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16. Abstract ERTS-1 imagery is proving to be exceptionally useful in delineating structural features in Alaska which have never been recognized on the ground. Previously unmapped features such as seismically active faults and major structural lineaments are especially evident. Among the more significant results of this investigation is the discovery of an active strand of the Denali fault. The new fault has a history of scattered activity and was the scene of a magnitude 4.8 earthquake on October 1, 1972. Of greater significance is the disclosure of a large scale conjugate fracture system north of the Alaska Range. This fracture system appears to result from compressive stress radiating outward from around the outside of the great bend of the Alaska Range at Mt. McKinley. One member of the system was the scene of a magnitude 6.5 earthquake in 1968. The potential value of ERTS imagery to land use planning is reflected in the fact that this earthquake occurred within 10 km of the site which was proposed for the Rampart dam, and the fault on which it occurred passes very near the proposed site for the bridge and oil pipeline crossing of the Yukon River.			
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I: INTRODUCTION

This report summarizes the work performed and conclusions reached during the first six months of contract no. NAS5-21833, ERTS-1 project no. 110-12, "Evaluation of feasibility of mapping seismically active faults in Alaska".

During the reporting period, ERTS-1 MSS imagery of 72 scenes of central and southcentral Alaska were received and inspected. Initial receipt, logging, and dissemination was carried out under ERTS-1 project 110-1, with A. Belon as principal investigator. This project functions as the central coordinating facility for all 12 University of Alaska ERTS-1 projects, and is receiving imagery for the entire state. In addition to the satellite data, the principal investigators for the present project participated in NASA aircraft (NP3A) flights over several areas of particular interest.

Examination and analysis of the aircraft and ERTS-1 data during the first six months of this project has revealed a good deal of new information regarding the tectonics of Alaska. By combining these results with known seismicity patterns, a new picture of tectonic deformation and associated seismic risk is beginning to emerge.

II: STATUS OF PROJECT

A. Objectives

A primary objective of this project was (as the name implies) to identify, on ERTS-1 imagery, seismically active faults which were unmapped, but suspected on the basis of ongoing seismicity. Aircraft data were to be obtained along a few of the more strongly suspected features to provide a measure of ground-truth. The overall objective was to combine these data with information from the University of Alaska's seismographic network in order to work out a model of how central Alaska is being deformed tectonically. Because of the very limited amount of geologic mapping available for the Alaskan interior, and the extreme difficulty encountered in obtaining such mapping in the field, ERTS imagery was felt to provide the ideal media by which to obtain the missing information.

B. Accomplishments During the Reporting Period

1. Preliminary Investigations

The University of Alaska's telemetered seismographic net has been in operation since late 1967 (Berg et al., 1967). Since that time, somewhat over 15,000 earthquakes occurring in central and southcentral Alaska have been located and catalogued. A recent compilation (Gedney et al., 1972) reveals that, very often, earthquakes in the Alaskan interior tend to cluster in linear zones where no faults are mapped. The manner in which these zones

occur strongly implies that the interior is composed of a number of abutting, rigid crustal blocks, and that earthquakes occur along their common boundaries and at the intersections of three or more blocks. The correlation of the observed pattern of suspected faulting with a suitable stress field has proved to be a difficult problem. We find that no single principal stress direction or smoothly varying family of principal stress trajectories can be identified which will yield the movement indicated simultaneously on these faults. Clearly, we needed more information on the location and geometry of other members of the fault system which we had not yet identified.

In order to obtain more information on a number of suspected fault lines, and to provide a measure of "ground truth" with which to compare the later ERTS imagery, a number of these lines were flown with NASA aircraft (NP3A) during the summer of 1972. Some results from this preparatory data acquisition are given in the section on "Results".

2. Applicability of ERTS-1 data to Project Objectives

Because of the sheer inaccessibility of most of interior Alaska to the field geologist, remote sensing techniques are a vital tool. Much of the mapping in the interior has been accomplished on the basis of aerial photography. However, this method does not provide the synoptic aspect which has such an important bearing on the applicability of the ERTS data. Linears may be traced on the ERTS images for hundreds of kilometers under similar lighting conditions. A mosaic composed of aerial photographs showing only short segments of the same linear and produced, in all probability, at different times of the year and at different hours, is many times more difficult to work with. We have found the NASA aircraft data which we acquired to be helpful in delineating faults and other structural features of a minor nature. However, for mapping the gross tectonic features of Alaska, and for an overview of how the whole pattern of deformation is occurring, it is our experience that the ERTS-1 imagery is vastly superior (and, obviously, more economical). We also find that, for our purposes, special enhancement techniques are generally unnecessary. Routine aerial photo interpretation practices (such as stereoscopic viewing with side-lapping pairs) have seemed entirely adequate up to the present.

3. Results

Some comments on ERTS-1MSS imagery The different characteristics of the various MSS bands in water penetration have been reported by various investigators, and will not be repeated here. Our investigation deals primarily with surface features, and we have found a good deal of disparity in the usability of the imagery, depending on band and on sun angle. Under the higher sun angles, we have found band 5 to give the most detailed images, showing cultural features such as roads particularly well. Under very low sun angles, however, we have preferred band 7, primarily because of its haze-cutting characteristics.

A "washed-out" appearance, though, giving very little contrast, is obtained from band 7 under high sun angles. In order to combine the best characteristics of each band, we have done a limited amount of false-color image preparation by the 3-M color key process. It is our experience however, that the limited amount of new information obtained (i.e., of limited significance to our investigation) is outweighed by the difficulties encountered in accurate registration of the images, and we have preferred instead to produce and view the different bands separately, choosing whichever seems to be superior under the conditions at the time.

Some recommended changes to previously mapped tectonic features.

The western escarpment of the Kenai Mountains does not appear on geologic and tectonic maps as being a normal fault (c.g., Dutro and Payne, 1957; King, 1969). It appears certain from the ERTS-1 imagery, however, that this is the case, and further, that several parallel faults exist within the Kenai Mountains themselves (Image ID nos. 1103-20513 and 1103-20520). In addition, this normal fault appears to extend northward across the Matanuska River and form the western escarpment of the Talkeetna Mountains (Image ID no. 1103-20511). This line appears to form one side of a very large graben including Cook Inlet and the whole of the Susitna River Valley. The other edge of the graben is formed by the Eastern Flank of the Alaska Range.

The Shaw Creek Fault, east of Fairbanks, has not generally been accepted by many geologists as being a true fault (F. Weber, U.S.G.S., personal communication). From the ERTS-1 imagery, however, it is evident that, not only is it a major structural break, but that it offsets the Tintina trench left-laterally, and that it extends across the Yukon to the north (Image ID nos. 1029-20381 and 1029-20383).

New findings relating to the tectonics of Alaska. The Totschunda fault has at least one unmapped branch at its intersection with the Denali fault (Image ID no. 1081-20275). In this scene it appears obvious that a strand of the Totschunda fault extends northwestward through Stone Creek, across the valley of the Nabesna River and into the mountains to the northwest. However, the most detailed geologic map available of this area (Richter, 1971) does not show this feature, presumably because of alluvial fill along its trace, lack of rock differentiation across it, and sheer inaccessibility in the mountainous areas. This scene also shows a small unmapped fault on the northwest flank of Mt. Sanford. It is evident from lighting and stream incision that it is a reverse fault.

One of the primary objectives of this investigation was to identify seismically active faults which had been postulated on the grounds of ongoing seismic activity. After several years of data accumulation, we are finding that earthquakes in central and south-central Alaska very often occur in elongated clusters where no faults are mapped. ERTS-1 imagery is being found to be extremely useful in identifying faults in these areas. A particularly good example is found in image ID 1066-20444. A seismically active strand of the Denali fault can easily be traced for a least 120 km with end points at approximately 62°26'N, 149°23'W, and 63°14'N, 147°44'W. It forms

a lineal depression along which streams flow and sag ponds form. Seismicity records dating back to 1967 reveal that earthquakes have tended to cluster along the fault in this area, particularly near the end points, and the southern end was the scene of a magnitude 4.8 earthquake on October 1, 1972. This earthquake was felt throughout the Susitna River Valley. Although it appears from the image that the Susitna River is offset left-laterally by the fault, the focal mechanism solution obtained for the event of October 1 indicates right-lateral displacement, which suggests that it is a strand of the Denali fault, and not a conjugate, or tear fault.

North of the Alaska Range, in the central interior, there is a broad zone of shallow seismicity which extends at least as far as the southern Brooks Range (Gedney et al., 1972). Since 1904, eight earthquakes of magnitude greater than 6.0 (up to 7.8) have occurred in this area. Although considerable seismic data has been accumulated for this region, primarily in recent years, geologic and tectonic mapping has been minimal or nonexistent. In October, 1968, an earthquake of magnitude 6.5 occurred in the Minook Creek Valley northwest of Fairbanks. Minook Creek valley appears on image ID no. 1105-21015 at approximately 65.4°N, 150.1°W. Prior to the 1968 earthquake, this feature was not recognized as a fault. Since that time, aftershock studies, fault plane solutions, and geologic field mapping have revealed that it is, indeed, a left-lateral fault. Had ERTS imagery been previously available, this conclusion would undoubtedly have been reached long ago. The extreme sharpness of stream incision, the textural and tonal differences across it, and the series of parallel fractures in the mountains around it would have left little doubt. Although the left-lateral nature of the system is not immediately apparent along Minook Creek, the third parallel feature to the east shows it quite well, with truncation of mountain lobes on both the north and south sides of the ridge line.

On closer inspection, one sees that the Minook Creek fault is only part of a large scale fracture system involving many other linears. Parallel features can be seen in the mountains across the Yukon River to the northwest, they can be identified on the southeast banks of the Yukon where they affect stream drainage, and two long parallel lineaments are seen in the Kuskokwim mountains to the southwest (Image ID no. 1105-21021). Textural changes occur across the latter two, although they become lost in the alluvium of the Tanana River at their northern ends.

An almost equally impressive set of conjugate fractures intersects the Minook Creek complex at an angle of 55°, and strikes southeast to the Alaska Range. This is roughly the dihedral angle at which most brittle substances would be expected to fail if compressive stress had been applied at an azimuth bisecting the acute angle between the two sets. In this case the direction is at an azimuth of 345°, roughly perpendicular to the trend of the Alaska Range. The conjugate set is most apparent in the Ray Mountains, across the Yukon River from Minook Creek; but it is also visible in the mountains around Minook Creek, south of the Tanana River, and near the Toklat River northwest of Mt. McKinley (Image ID no. 1105-21021). The latter lineament appears to truncate a small mountain near its center.

There is a strong implication that earthquakes in this area are the result of compressive stress radiating outward from around the great bend in the Alaska Range at Mt. McKinley, and that this stress system has resulted in the formation of a conjugate shear system with earthquakes occurring along the individual fractures. A mechanism of this sort agrees well with the fault plane solution obtained for the 1968 earthquake, and with one obtained for a magnitude 6.0 event near Fairbanks in 1967 (Gedney, 1970). For the latter event, a nearly north-south azimuth of compressive stress was obtained, nearly perpendicular to the Alaska Range at this point, as was true of the Minook Creek event. The 1967 earthquake occurred on a prominent lineament extending from the town of Nenana, past Fairbanks, and into the headwaters of the Chena River to the northeast. As a suspected fault, this line was flown with a NASA aircraft (NP3A) during the summer of 1972. While conventional and reflective infrared photography failed to reveal conclusive evidence of faulting (as did side-looking radar), the IR scanner produced some unusual and unexpected results. Just south of Fairbanks, on the Chena lineament in the aftershock zone of the 1967 earthquake, there are what appear to be a series of steeply dipping folds. Their appearance virtually rules out the possibility that they are old river meanders. They are in an area which is normally regarded as being overlain by thick flood plain deposits, which makes it seem unlikely that they are a reflection of the underlying bedrock. The fold axes trend generally along the line of the Chena lineament, with an amplitude of about 7 km and a period of about 3 km. It is conceivable that they are a result of deformation of the Quaternary sediments by compressive stress in a north-south direction (Mission 209, roll 48, site 314, frame 134). Their appearance on the IR scanner may reflect the influence of these folds on the groundwater level.

The area of the Minook Creek fracture system contains two additional faults, not apparently related to the Minook Creek system, but unmapped and clearly visible on the ERTS-1 imagery. Perhaps these should not be called "new" faults, since they have been partially mapped, but incorrectly as it would appear from the ERTS data. Existing tectonic maps show the Tintina fault executing an abrupt turn near $65^{\circ}45'N$, $147^{\circ}W$ and heading southwest roughly paralleling a recently mapped thrust fault complex. It would appear from the ERTS images that, instead, the main branch of the fault extends up Victoria Creek with only a slight bend, and on to the Yukon River almost due west, terminating near $65^{\circ}38'N$, $149^{\circ}51'W$. Just northwest of this fault, and roughly parallel to it is another fault which extends from the Ray Mountains, across the Yukon River, and well into the Yukon Flats to the northeast. Only a small part of the center section of this feature has been recognized as a fault on the ground (R. Chapman, U.S.G.S., personal communication) (Image ID nos. 1105-21012 and 1105-21015).

If an outwardly directed compressive stress field around the great bend in the Alaska Range is a qualitative approximation of conditions actually existing here, a logical question which now arises is, "What causes the compressive stress?". A possible explanation is that the forces which caused the Alaska Range to "buckle", forming the great 90° bight in the range at Mt. McKinley, have not yet subsided and further deformation is occurring. The primary cause is probably related to underthrusting of the north Pacific plate beneath the continental

margin along Cook Inlet and the western Alaska Range (Davies, 1973); but whatever the basic energy source, it would seem plausible that further buckling of the range would result in outwardly directed compressive stress around the outside of the bend, with a resulting pattern of conjugate fractures of the type we have been discussing.

Although our discussion has dealt primarily with tectonic aspects of Alaska which can be seen on ERTS imagery, the most salient point is this: It is possible, with ERTS data, to delineate seismically active faults which may go otherwise unnoticed. Certainly the Minook Creek fault (site of the magnitude 6.5 earthquake of 1968) would have been recognized long ago, had ERTS imagery been available, and its freshness of appearance would have labeled it as being recently active. The potential impact of ERTS data on construction and planning purposes is well pointed out by noting that the proposed site for the Rampart dam in interior Alaska was within 10 km of the 1968 earthquake, and further, that the proposed site for the Rampart bridge and oil pipeline crossing of the Yukon River is very near the Minook Creek fault if it is extended slightly to the north. Particularly in Alaska, where these areas are remote and accessible only at great time and expense, ERTS imagery shows great promise as an aid in construction planning, zoning, and seismic risk evaluation.

III: NEW TECHNOLOGY

None

IV: PLANS FOR NEXT REPORTING PERIOD

During the next bi-monthly period, we intend to spend much of our time completing the search of our test area for further unmapped tectonic features. Much of our effort to date has dealt with central interior Alaska, and only cursory inspections have been made of certain regions; for instance, the Chugach Mountains in south-central Alaska. We anticipate no significant change in our methods of operation, i.e., we will continue to individually inspect image products produced in-house from the 70mm bulk negatives, and we will hold seminars and discussion groups utilizing lantern slide projectors and the 70mm positive transparencies. One such seminar is scheduled for the third week in March, in which persons from various geologic disciplines on the University of Alaska campus will participate.

During the next six months reporting period, data accumulated from the early spring passes will be inspected and compared with that already obtained. Consolidation of all the information obtained will be carried out, and the final data products (i.e., mosaics, overlays showing new features, etc.) will be produced, together with a statement of the overall findings of the investigation.

V: CONCLUSIONS

It is entirely feasible to map seismically active faults strictly on the basis of ERTS imagery. The seismicity of the Alaskan interior is primarily the result of outwardly directed compressive stress around the bend in the Alaska Range at Mt. McKinley. ERTS imagery provides a valuable source of information for new construction planning, zoning, and seismic risk evaluation.

VI: RECOMMENDATIONS

None.

VII: PUBLICATIONS

None as yet.

VIII: REFERENCES

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APPENDIX A: CHANGE IN STANDING ORDER FORMS

None.

APPENDIX B: ERTS DATA REQUEST FORMS

None.

APPENDIX C
ERTS IMAGE DESCRIPTOR FORM
(See Instructions on Back)

DATE 20 Feb 73

PRINCIPAL INVESTIGATOR Larry D. Gedney

GSFC UN601

ORGANIZATION Geophysical Institute, University of Alaska

D _____
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ID _____

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Fault	Mountain	River	
110420554	x	x	x	city glacier glacier glacier, volcano
110420560	x	x	x	
110420563	x	x	x	
110420565	x	x	x	
110420572	x	x	x	

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APPENDIX D: SIGNIFICANT RESULTS

PRINCIPAL INVESTIGATOR: Larry D. Gedney

TITLE OF INVESTIGATION: Evaluation of feasibility of mapping seismically active faults in Alaska.

DISCIPLINE: Mineral Resources, Geological Structure and Landform Surveys.

SUBDISCIPLINE: Earthquake zones investigations.

SUMMARY OF SIGNIFICANT RESULTS:

The western escarpment of the Kenai Mountains south of Anchorage, Alaska, does not appear on geologic and tectonic maps as being a fault, although the possibility has been suggested by some workers. However, on ERTS-1 imagery (Image ID Nos. E-1103-20513 and E-1103-20520), it appears certain that the mountain front is the scarp of a very large normal fault, and further, that at least two parallel faults exist within the Kenai Mountains themselves. In addition, this fault appears to extend northward across the valley of the Matanuska River and form the western escarpment of the Talkeetna mountains north of Anchorage (Image ID No. E-1103-20511). This line of faulting appears to form one side of a very large graben including Cook Inlet and the whole of the Cook Inlet Lowlands. The other edge of the graben is formed by the eastern flank of the Alaska Range.

The Shaw Creek fault, east of Fairbanks, has not generally been recognized by many geologists as being a true fault. From the ERTS-1 imagery, however, it is evident that, not only is it a major structural break, but that it has left-laterally offset the Tintina trench, a major strike-slip fault system north of Fairbanks, and that it extends across the Yukon River to the north (Image ID Nos. 1029-20381 and 1029-20383).